Simulation of space weathering of HED meteorites by laser impulse irradiation. J. T. Wasson*, C. M. Pieters[†], A. V. Fisenko[‡], L. F. Semjonova[‡], L. V. Moroz[‡] and P. H. Warren*. *University of California, Los Angeles, CA 90095 USA; [†]Brown University, Providence, RI 02912 USA; [‡]Vernadsky Institute of Geochemistry and Analytical Chemistry, 117975 Moscow, Russia

A major puzzle of meteorite-asteroid science is why only one large (D≥40 km) asteroid shows a basaltic reflection spec-trum even though meteoritic evidence demonstrates that many asteroids were heated enough to melt and differentiate. Collisions may have removed the surfaces of half the large asteroids, but a sizable fraction should retain their original surfaces. Although space weathering is the obvious explanation, most asteroid researchers seem to doubt that there are plausible processes that would convert a sharply defined basaltic spectrum such as that of the asteroid 4 Vesta to the more common spectral (e.g., S-type) types found in the inner part of the Asteroid Belt where most meteorites are thought to originate. We hypothesize that space weathering, in particular the generation of tiny pockets of melt similar to those produced by micro-meteorite impacts, alter basaltic spectra in ways that make them indistinguishable from some S-type asteroids. If this is correct, there may be several additional basalt-covered asteroids in the Asteroid Belt that are potential HED parent bodies.

The other major puzzle of meteorite-asteroid science is why no large asteroid has a reflection spectrum similar to ordinary chondrites, the most common meteorites to fall. To address this problem some of us (Moroz et al., 1996) carried out an experi-mental study on the L5 chondrite Elenovka. Powdered samples were irradiated *in vacuo* with pulses from a Nd-YAG laser (λ = 1.06 µm, pulse length ≈0.8 µs, beam diameter ≈100 µm, 30-40 kHz). The laser treatment produced melts that chilled to form mixtures of fine crystals and glass. Relative to unal-tered Elenovka, the spectra of irradiated samples showed a decrease in the depth of the 0.9 µm band, a decrease in the albedo, an increase in redness, and a decrease in the 1.9-µm-band/0.9-µm-band area ratio. Because the low-Ca pyroxene that is the main source of the characteristic bands in L chondrites is also the dominant contributor to the bands in howardites, eucrites and diogenites, it seemed worthwhile to carry out a similar study on HED meteorites.

We applied the original procedure for the eucrite Millbillillie and the diogenite Johnstown. A sample of a terrestrial pyrox-enite was used as a control. Samples were ground, and a powder with grain size <75 µm subjected to irradiation in the vacuum laser facility used in the previous study. After the laser treatment the samples were again sieved at 75 µm and thick sections for petrographic study (including EPMA) prepared from both size fractions and from the pre-irradiation powder.

The laser pulses converted the affected regions of the original finely crystalline samples into blobs of glassy material with abundant vesicles and scat-tered relict and newly formed skeletal crystals. The blobs tended to adhere to one another, forming aggregates up to about 3 mm in length. We designate the post-irradiation fractions finer than 75 µm as “partially altered,” because they contain much less glass than the coarse fractions. In the case of Millbillillie, the <75 µm frac-tion is virtually glass-free, whereas the >75 µm fraction appears to be well over 50% glass. The glass composition is heterogeneous, but generally very similar to that of the bulk eucrite (e.g., 12 wt% Al_2O_3); Na and K were somewhat lower, suggesting partial volatilization. The remaining crystals are in general similar in composition and relative proportions to the original Millbillillie assemblage.

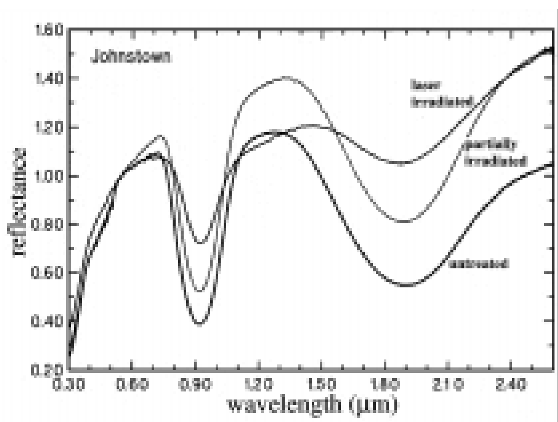
The post-irradiation <75 µm fraction of Johnstown has a much higher proportion of alteration products than its Millbillillie counterpart. Roughly 3 vol% consists of glassy spherules up to 60 µm in diameter. The glass is quite uniform and roughly bulk-Johnstown in composition, but the larger spherules tend to be less thoroughly glassy, and one contains a surprisingly coarse (20×5 µm) relict (?) olivine, which is reversely zoned, but mainly Fo_{75}. A few small FeS spherules are also present. The remainder of this fraction is mostly unal-tered orthopyroxene, although 5-10% of the crystalline grains show possible irregulari-ties that are not yet adequately character-ized. The >75 µm fraction of Johnstown consists almost entirely of a texturally com-plex material with composition scarcely resolvable from bulk Johnstown (i.e., nearly pure opx), but featuring heterogeneity at the 1-5 µm scale not found in unaltered Johnstown pyroxene. For example, if regarded as pyroxene (the stoichiometry is almost correct), points only 3 µm apart range from $En_{54}Wo_8$ to $En_{76}Wo_3$. This material probably formed by rapid crys-tallization of bulk-Johnstown melt. Among the rare crystals, a 20×12 µm grain of pure silica is noteworthy, considering that Fo_{75} olivine is present elsewhere.

The spectra of both Johnstown and Mill-billillie were altered by the impulse laser treat-ment, but the two samples produced quite different products. These differences probably reflect the compositional contrast between dio-genite and eucrite, but to some degree (as-yet poorly constrained) they might simply reflect small variations in the laser procedure. For Johnstown the laser treatment reduced the al-bedo about a factor of two and also reduced the strength of the pyroxene absorption near 0.91 µm by 50%. The continuum slope across the ferrous absorption was not affected, but the continuum in the visible became slightly flatter. Band centers scarcely changed, but the irradi-ated sample exhibits an additional slight inflec-tion near 1.25 µm due to an unknown alteration product.

The laser treated Millbillillie samples gave unexpected spectra. Because it is so glass-poor, the partially altered sample is essentially identical to the original mete-orite. In contrast, the spectrum of the altered sample contains only a few of the original features; the albedo was lowered ≈20% and the original pyroxene features were replaced by those of alteration pro-ducts (mainly glass) The continuum across the ferrous absorption became flatter whereas the visible continuum became slightly redder. We plan to repeat the laser experiment with a smaller dosage.

If the laser treatments mimic the effects of flash melting by micrometeorite impacts, then it is clear that key spectral features of these materials are altered in the process. It is, how-ever, not yet clear what detailed spectral prop-erties the altered surface of an HED parent body would exhibit and whether these properties are closely similar to observed spectra of asteroids.

Fig. 1. Scaled reflectance spectra of the Johnstown diogenite before and after la-ser irradiation. The “laser irradiated” sample contains more alteration products than the “partially irradiated” sample.



Reference: Moroz L.V., Fisenko A. V., Sem-jonova L. F., Pieters C. M. and Koro-taeva N. N., Icarus **122**, 366-382 (1996)